Dry Etch Damage of Gallium Nitride

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Abstract:

Gallium Nitride (GaN) is a semiconductor material that offers great potential in the development of photonic devices. In the making of these devices, the material is exposed to dry etch conditions that may cause damage to the lattice. In this study we use transmission line model (TLM) measurements to assess the damage caused by varying doses of 500 eV of Ar^+ ions in GaN. The total resistance of the material increased with increasing dose. At current densities of 0.006 mA/cm^2, 0.06 mA/cm^2 and 0.6 mA/cm^2 with a fixed time of 15 min., both contact and sheet resistance increased. At varied exposure times of seven and a half, fifteen, and thirty min., with a current density of 0.06 mA/cm^2, the contact resistance increased while the sheet resistance decreased after 30 min. By varying the current density, bombardment time, and dose of Ar^+ ions, we hope to learn more about ion damage mechanisms in GaN.

Report:

Gallium Nitride (GaN) is a material used in making blue light emitting diodes, laser diodes, photovoltaic cells and photodetectors. Because of strong chemical bonds, GaN is very resistant to wet chemical etching, thus, dry etching is used in device fabrication. Dry etching combines a chemical component, reactive gas, with a physical component, high energy ions, to enable material removal. In doing so, however, damage may be introduced to the lattice by the incident ions. Thus, it is important that we characterize the ion damage in GaN.

Samples of GaN were bombarded with 500 eV of Ar^+ ions at different doses. Some samples were ion bombarded for 15 min. with current densities of 0.006 mA/cm^2, 0.06 mA/cm^2 and 0.6 mA/cm^2. Other samples were bombarded with 0.06 mA/cm^2 for 7.5 min., 15 min., and 30 min. Following bombardment, transmission line model (TLM) patterns were fabricated by using photolithography and metal deposition. The contacts were annealed at 850°C for 30 sec. The samples were then electrically probed. Both contact and sheet resistance were calculated for each sample. The transmission line model (TLM) was used because it gives an electrical representation of the physical characteristics of the material. Damage in the material will result in a change of resistance.

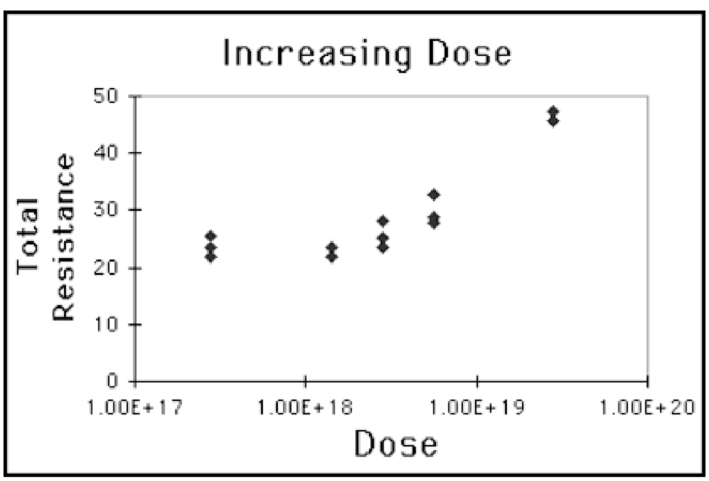

Fig. 1 . The total resistance increased with increasing dose.

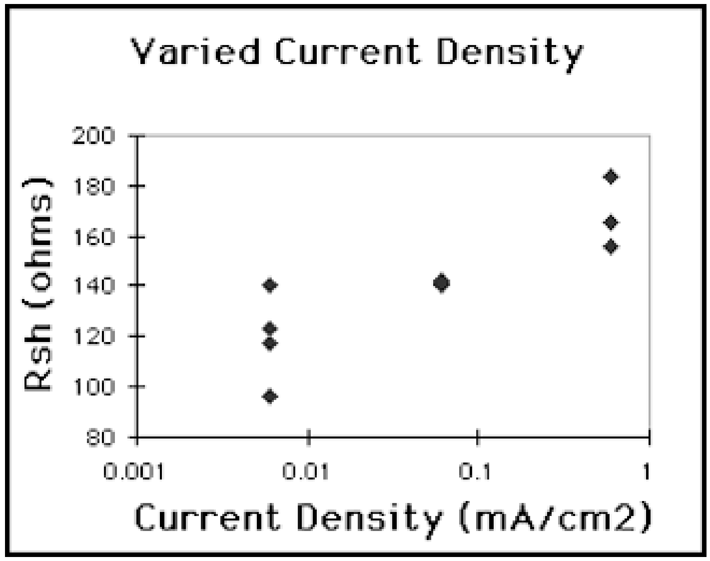

Figure 2. Increasing the current density by an order of magnitude increases sheet resistance.

The total resistance increased with the increasing dose. As the dose of bombardment increased, so did the damage in the sample (figure 1). A comparison was made to show how contact and sheet resistance vary with time and current density. For sheet resistance, results show that increasing the current density by intervals of an order of magnitude also increases sheet resistance. Which means that more damage is created with increasing current density (fig 2).

Increasing the exposure time does not show a definite trend. Sheet resistance does increase from 7.5 to 15 min., but at 30 min. the resistance decreases (figure 3). It brings up the question of what kind of damage is caused at long term exposures. In order to find out, more work must be done to find out how and where the ions are damaging the material.

The results for contact resistance show that no observable change exists until higher current densities or exposure times are used. At 7.5 and 15 min. the contact resistance was similar. Yet, a noticeable change occurred at 30 min. (figure 4). Contact resistance showed

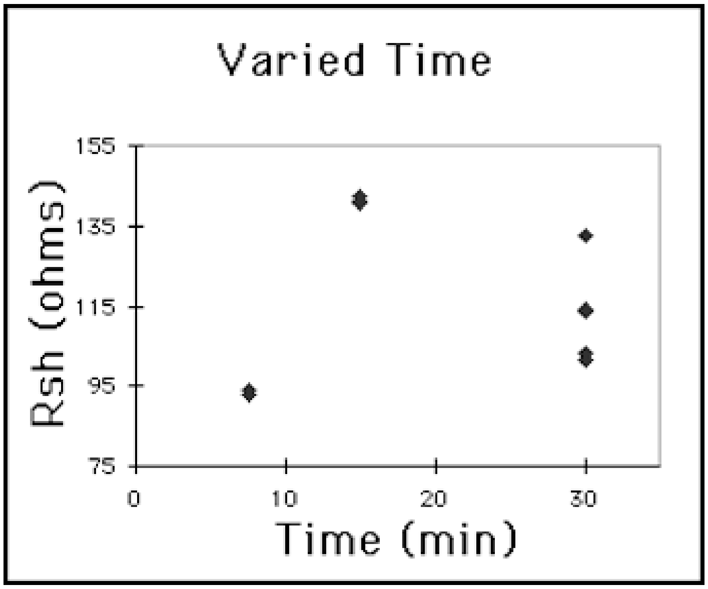

Figure 3. Sheet resistance increased from 7.5 min. to 15 min. but decreased after 30 min.

a similar trend with varied current density. It remained the same at 0.006 mA/cm^2 and at 0.06 mA/cm^2 but significantly increased at 0.6 mA/cm^2 (figure 5).

From our data, we were able to conclude that the total resistance of the material increases with increasing dose. Which means that more damage is created at higher doses. Since there was a difference between the change in sheet resistance caused by varying current density and varying exposure time, additional work is needed to investigate where the damage is being caused. The damage increased as the current density increased by an order of magnitude from 0.006 mA/cm^2 to 0.6 mA/cm^2. For the contact resistance, no significant change occurs until the material is exposed for thirty minutes of time or until a very high current density of 0.6 mA/cm^2 are used.

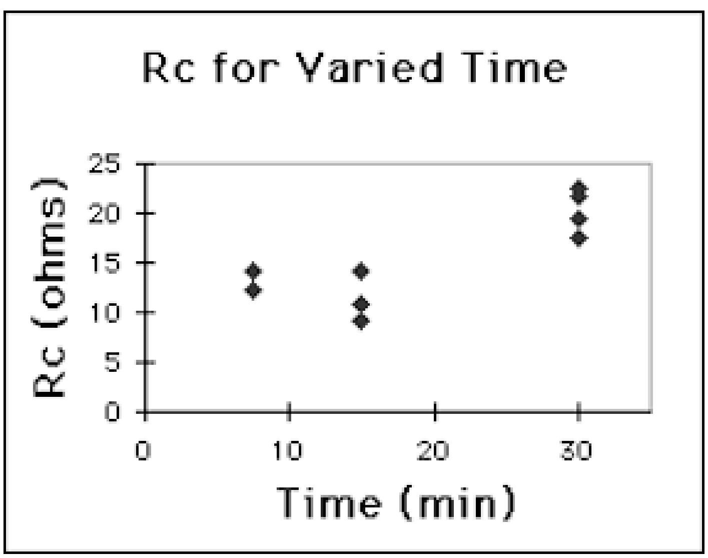

Figure 4. No significant change in contact resistance is observed until an exposure of time 30 minutes.

Acknowledgments:

I would like to thank my mentor Elaine Haberer for helping me so much with my research. Also, I would like to thank everyone at UCSB for providing us with such a great experience.

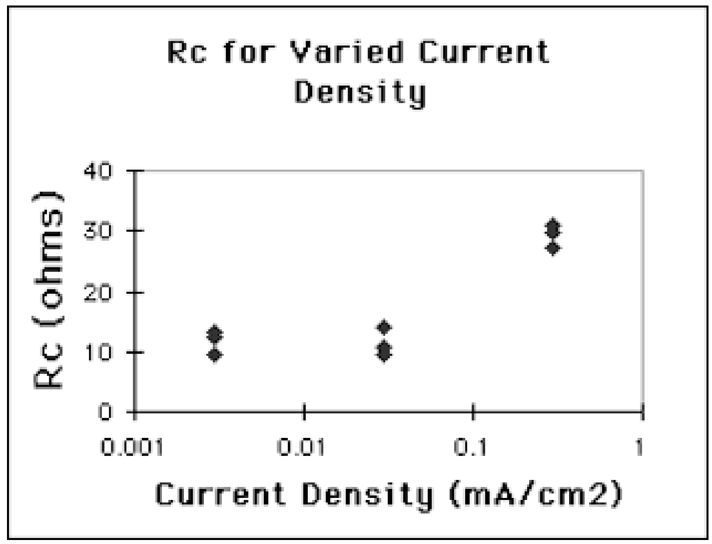

Figure 5. Sheet resistance noticeably increases when a current density of 0.6 mA/cm^2 is used. At current densities of 0.006 mA/cm^2 and 0.06 mA/cm^2 no significant change is observed.